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Recent Developments in Breeding for the Control of Potato Blight

D. H. LAPWOOD

Rothamsted Experimental Station, Harpenden

LOSSES from potato blight, *Phytophthora infestans* (Mont.) de Bary, can occur in two ways: by prematurely defoliating the haulm which prevents tubers from developing fully, and by infecting tubers at, or before, lifting. Control measures have been directed at prolonging the growth of the haulm and at decreasing tuber infection, especially at lifting, which has meant using costly sprays, labour and machinery. The alternative is to breed varieties immune or resistant to the disease, and it is the purpose of this article to review briefly developments in breeding for "immune" varieties, giving reasons for their failure, and outlining alternative forms of resistance.

Breeding for Immunity through Hypersensitivity

The search for suitable breeding material began after the Irish epidemics of 1845 and 1846, with the hope of finding immunity to the disease in the wild tuber-bearing species of *Solanum* in Central and South America. Although immunity was never found, high levels of resistance were discovered in several species, and some clones of one species, *Solanum demissum*, were so slightly affected that for a time it passed as "immune". This species was crossed with the cultivated potato (*Solanum tuberosum*) and the progeny were also little affected by blight. This apparent "immunity" was later found to result from the hypersensitivity of the host cells to infection. After the fungus penetrates the host, the cells immediately surrounding the site of infection quickly die and the pathogen spreads no further. To distinguish this reaction from true immunity, in which the pathogen does not infect the host, the term "*field immunity*" is often used.

Although in 1911 Salaman showed, with the *S. demissum* hybrids, that blight resistance was an inheritable character, it was not until some thirty years later that the first "hypersensitive" varieties were produced. During this long period, which is covered by other reviews [1], [2], suitable hybrids had to be produced using the wild species. Then, by a series of backcrosses to cultivated varieties, and selection of the progeny, hypersensitivity was retained, the unwanted wild characteristics were gradually eliminated and commercial qualities re-introduced.

In the early 1930s blight was found on selected seedlings which had previously been immune, and tests showed that this outbreak was caused by a race of the fungus different from the one previously recognized. Breeders had little doubt that the variability in the pathogen

then apparent could be overcome, but later as more hybrids were produced more races of the fungus were gradually discovered.

When the hypersensitive varieties were introduced they were at first successful, but when grown on a commercial scale for only a few years they were attacked by new races of the fungus. Many of the new varieties then proved more susceptible to blight than many existing varieties. Only by growing hypersensitive varieties did the extent to which the fungus varied become detectable.

DIFFERENT RACES OF THE FUNGUS

Potato breeders used this fungal variation to analyse their potatoes genetically and showed that the hypersensitive reaction of *S. demissum* is controlled by at least four major genes: R1, R2, R3, and R4 [3]. The genes are on different chromosomes and therefore can be inherited independently, making possible 16 genotypic combinations. Sixteen different races were postulated as being required to overcome all the different combinations, and over a number of years all 16 races have been found, a variability in the fungus that had never been expected. The discovery of two further independently segregating genes R5 and R6, makes 64 genotypes possible, which provide the means of identifying 64 different races of the fungus. It is likely that all will be found somewhere or other, for since Gallegly and Galindo [4] reported in 1957 that the sexual stage of the fungus occurs in the field in Mexico, the variations need no longer be entirely asexual. Previously, although sexual reproductive bodies had been produced in culture, only the asexual stage was known in the field, but now there are obvious possibilities of new genetic forms arising from sexual reproduction.

To produce fertile oospores two mating types are required; fortunately all European races so far isolated belong to one mating type and the sexual stage has not been reported in Europe [5]. Mexican races will mate with their European counterparts because they belong to the opposite mating type. With the sexual stage occurring in Mexico, it is not surprising that Niederhauser reported in 1954 that no clones of *S. demissum* were "immune" to the disease [6]. Breeders now realize that, with the wide distribution of most of the known races, hypersensitivity will rarely last and that R genes alone are not adequate protection against the disease.

The individual races of the fungus are identified by testing their reactions on differential host plants that contain different combinations of the four R genes [7]. The name of the race is based on R genes which fail to protect the particular genotype by giving a hypersensitive reaction, or more simply on the R genotypes the particular isolate can attack successfully. Thus, race 1,2,3,4 attacks all combinations of the four R genes, whereas race 1,2 attacks only plants containing either or both R1 and R2, and a hypersensitive response will be given on all genotypes containing R3 or R4. Isolates that produce a hypersensitive response on all the differentials are designated race O, implying that

they will attack only normal susceptible varieties. Race 4 is the one most often isolated from commercial varieties in epidemics in this country and is often termed the "common race".

HYPERSENSITIVE VARIETIES ATTACKED BY "LATE STRAINS"

Growers in this country have experience with the hypersensitive varieties only in the last few years, but already they are worried by the way the so-called "immune" varieties behave in epidemics. The varieties so far grown contain only one R gene, either R1 or R3. Field experience has shown that the hypersensitive varieties are attacked some three or four weeks later than susceptible varieties and this has been attributed to the appearance of a "late strain" of the fungus. The "late strains" from 'Ulster Torch' (R1) and 'Pentland Ace' (R3) are often 1,4 and 3,4 respectively. The apparent breakdown of hypersensitivity and the unexpected susceptibility of the hypersensitive varieties when attacked, has led to the belief that "late strains" are more aggressive than the "early strains" which attack the older fully susceptible varieties.

As a result growers are afraid that, should these "late strains" become more common, their fully susceptible varieties may be more seriously damaged than in the past. However, the ability to overcome hypersensitivity is not a measure of aggressiveness, even in a variety containing four R genes, and there is no reason why the "late strains" should be any more aggressive than race 0 or race 4. The virulence or aggressiveness of different isolates of the same race can vary, but there is no evidence that aggressiveness increases with the complexity of the race. Nor is there any basis to fear that the "late strains", because of increased virulence, will allow blight to spread from tuber to tuber in the clamp.

MULTIPLICATION OF BLIGHT FUNGUS ON SUSCEPTIBLE VARIETIES

The late infection of hypersensitive varieties is most simply explained by assuming that the races responsible arise during the multiplication of the blight fungus on nearby susceptible varieties [8]. At first there are few spores of races able to attack the hypersensitive variety, but later as the spore population increases, the hypersensitive variety is more likely to be attacked by spores of the appropriate race. Once a lesion is established and spores produced in the hypersensitive varieties, further spread will be rapid, provided the weather is suitable. However, once a late race overwinters successfully, conditions alter; the hypersensitive variety can be infected early and the race then classified as an "early strain".

Of those varieties that have completed trials only 'Orion' (R1) shows much resistance to blight, but its yellow flesh limits its usefulness as a commercial variety. 'Pentland Ace' (R3) and more recently 'Ulster Torch' (R1) are very susceptible both in haulm and tuber to races to which they are not hypersensitive. A feature with 'Pentland Ace' (R3)

is that it resists races on the haulm which readily infect the tuber [9], showing a differential effect of R3 gene on different tissues.

Breeding for Resistance

The hypersensitive varieties failed because of the unforeseen variability of the pathogen, and the failure was made more dramatic because of the susceptibility of the varieties once the protective reaction was overcome. If the disease cannot be controlled by breeding immune varieties, then an alternative is to try to decrease the damage it causes by breeding varieties with a high level of resistance against all races of the fungus. Resistance is likely to last when it is controlled by many different genes that affect susceptibility in various ways, so that a single change in the fungus will not overcome a single gene in the host. Such resistance is known as "*multigene*" or *field resistance* to distinguish it from hypersensitivity or *field immunity*, which is controlled by a few major genes.

Varieties with more than average resistance to blight have always existed and have been said to show some field resistance, as shown by the later infection, slower destruction of the haulm, or less loss of crop than in other varieties. Recent research has sought to find what characters determine field resistance, and whether they can be bred into commercial varieties either alone or with hypersensitivity. Varietal resistance may for simplicity be classified under three headings: "physiological", "morphological" and tuber resistance.

PHYSIOLOGICAL RESISTANCE

This describes the reaction of the host to an attack by the pathogen, and physiological resistance may be shown at various stages of the fungal attack. At the first stage, it may mean that only a small proportion of the spores that germinate on the surface of the host penetrate successfully, or perhaps only a proportion of penetrations establish infection. Or, at a second stage, the fungus may advance only slowly or produce spores only after a long period. Also, physiological resistance may show in few spores being produced, either because only a small area produces spores or because few are produced per unit area.

These characteristics are available to the plant breeder because existing resistant varieties possess at least some of them. If even more extreme types of behaviour could be found and incorporated into varieties, then the rate at which the disease spreads might be greatly decreased by delaying the development of the fungus at every stage.

MORPHOLOGICAL RESISTANCE

The structure of the individual plant and the type of canopy produced in the crop may affect the rate of development of the disease in several ways. The canopy and the nature of the leaf surface can affect its rate of drying after dew or rain, and the canopy may determine the duration of high humidity. To penetrate the host, the spores need water, and

high humidity is necessary for spore production. Destruction of the haulm in an epidemic is the result of numerous separate infections, and the rate of defoliation will depend to a large extent on how quickly all the foliage becomes infected. The structure of the individual plant, the leaf shape and its attitude, the number and density of leaflets will all help to affect the distribution of water droplets and, with the canopy affecting the rate of drying, will control the number of infection sites open to the fungus.

An open crop should allow leaves and soil to dry quickly and decrease the rate of infection. Obviously very wet weather will overcome this type of resistance, but the importance of morphological characteristics of a variety in relation to disease should not be underestimated. The breeder would be advised, whenever possible, to select more open and erect types and to avoid those which are lax-stemmed or straggling.

TUBER RESISTANCE

If varieties could be bred with immune haulms, tuber resistance would not matter because there would be no blight on the haulm to infect them. Where haulms are only resistant (as opposed to immune), however, tuber resistance is most important. A resistant haulm does not necessarily mean resistant tubers. Some varieties such as 'Irish Chieftain' have resistant foliage but susceptible tubers, whereas 'Golden Wonder' shows most resistance in the tuber. Others such as 'Majestic' or 'Arran Viking' can be left unsprayed, the foliage destroyed by blight, and still few tubers will be infected. More research is required into the reasons for resistance of all types, but certainly more attention must be paid to tuber resistance [10].

The potato breeder has two main sources of multigene resistance. One is the many varieties of *Solanum tuberosum* in cultivation throughout the world and the other, wild, tuber-bearing species of *Solanum*.

Within *S. tuberosum*, early maturing varieties are more susceptible to blight than the late maturing ones. Late varieties such as 'Champion II', 'Shamrock' and 'Northern Invincible' were being tested between 1911 and 1919 under Irish blight conditions and showed only slight infection when more susceptible varieties were already dead [11], but unfortunately lateness and poor commercial quality precluded them from becoming popular. Whether there is a definite linkage between late maturity and resistance is uncertain; if there is we shall have to find out whether it can be broken and the resistance transferred to maincrop varieties. The potato breeder wants to find a degree of resistance that will withstand the most severe blight conditions, and this may not occur in *S. tuberosum*.

The most extreme forms of resistance are found in the wild species of *Solanum*, e.g., *S. demissum* and *S. stoloniferum*, and these are being used as sources of multigene resistance. Many of these wild species are also hypersensitive and some breeders are attempting to combine both forms of protection into a commercially acceptable variety.

As the failure of the hypersensitive varieties is comparatively recent, many breeders are still looking for the most promising form of resistance. As already mentioned, some continue to use hypersensitivity but are now combining it with multigenic resistance, whereas others are hoping to produce suitable multigenic varieties. Much of the selection is being done in the field and promising seedlings are often sent to Toluca Valley in Mexico where epidemics can regularly be expected to be caused by a wide range of races. Simple laboratory tests will have to be devised to increase the numbers of seedlings that can be screened, and these are being developed. Haulm resistance is still emphasized and too little attention given to tuber resistance.

Success or Compromise?

Blight resistance is only one of the problems of the potato breeder, for not only does he have to find resistance to other pests and diseases but he must also produce a variety acceptable both to the farmer and the consumer. In this country there is particular need for a variety with the quality of 'King Edward' but with blight resistance both in the haulm and tuber, and for a 'Majestic' with improved quality. Whether blight can be controlled by a highly resistant variety, or whether effective control will eventually be a compromise between resistance and a limited spray programme, remains to be seen.

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Control of Fascioliasis

S. B. KENDALL

Central Veterinary Laboratory, Weybridge

IN MANY PARTS of the world infestation with liver flukes is an important cause of disease in domestic animals. Two species of *Fasciola* are involved; *F. gigantica* which is responsible for fascioliasis in tropical parts of Asia and Africa and *F. hepatica* which is found in temperate zones, and also high altitudes in, for example, North India and Kenya where it has probably been introduced from Europe. In Britain we have to deal only with *Fasciola hepatica* and with the single vector *Lymnaea truncatula*, a small snail rarely exceeding 0·8 cm long, characteristically found in shallow temporary water and on muddy ground subjected to frequent alternation of drought and flood. This snail is capable of aestivating* for a considerable period, and has the power of very rapid multiplication and growth when environmental conditions are favourable.

Multiplication of the Parasite

Infestation with small numbers of parasites may cause little apparent harm to sheep and very little harm to cattle, although it may result in condemnation of the liver when the animal is killed for food. Large numbers of parasites can be highly pathogenic and extremely heavy mortality may occur in flocks of sheep. Although even heavy infection with *F. hepatica* rarely kills cattle in Britain, it causes considerable loss in condition which is particularly serious in milking cattle.

In Britain, fascioliasis in both cattle and sheep occurs as a clearly visible disease mostly in the west, particularly in Wales, Devon and Cornwall and in Ireland, where climatic conditions of temperature and moisture encourage the multiplication of the snail and, as Dr. C. B. Ollerenshaw has stressed, also favour the different developmental stages of the parasite both in and out of the snail. For an epidemic to start, conditions must be suitable for the multiplication of the parasite, which means that there must be:

1. Plenty of viable fluke eggs on the pastures,
2. Adequate numbers of snails,
3. Plenty of food for their growth and for that of the contained parasites,
4. Suitable conditions both for the transport of the free-living stages in the life-cycle and for the survival of the encysted metacercariae (the infective stage) until they are picked up in numbers sufficient to cause disease in the grazing stock.

Broadly speaking, as Ollerenshaw has shown, an epidemic of liver

* Aestivation is a process, comparable to winter hibernation, by which the snail becomes inactive in dry summer weather.

fluke disease must be preceded by at least four months when fields are at full moisture capacity (i.e., when precipitation exceeds evaporation) and these four months must occur during the warmer part of the year because low temperatures limit development of the parasite. Even in the snail habitats of Western Britain, such rainfall conditions occur comparatively seldom—perhaps once in six or seven years on average—but it is then that fascioliasis becomes a major problem. Heavy mortality in the sheep population has occurred at intervals since the black years of 1879–81 when 3 million sheep are believed to have died from "the rot". During the winter of 1958–59 losses on an exceptionally heavy scale were experienced throughout the endemic areas of Britain.

Control Methods

The main lines along which control might be devised have been recognized for many years and are as follows:

TREATMENT OF STOCK

(*a*) *Control of disease.*

Carbon-tetrachloride, hexachloroethane, felix-mas and mixtures of these drugs are efficacious against adult flukes, but unfortunately have little or no effect against the immature parasites which are responsible for the heavy mortality seen in sheep during bad fluke years. The problem of safety in administration has to be considered with these drugs, e.g., carbon-tetrachloride can on occasion cause heavy mortality in particular flocks. It is not known why this should happen, nor has it proved possible to reproduce the syndrome in the laboratory (there is believed to be an association with high condition in the stock and with trough feeding). The overall incidence of the syndrome (having regard to the large numbers of animals treated each year) is low, but when it does occur a high proportion of a flock may die, with embarrassment to the veterinarian and the pharmaceutical firm that supplied the drug. Attempts are being made to resolve the difficulty by finding the underlying cause of flock susceptibility to poisoning or by finding a safer route of administration.

Some work on the production of a vaccine has been reported. However, unlike some other parasitic diseases, fascioliasis does not seem to be characterized by the development of an appreciable resistance to reinfection, so that the method does not appear to be very promising.

(*b*) *Reduction in output of fluke eggs.*

The known drugs are very effective in reducing the numbers of fluke eggs passed on to the pastures, so that in theory, routine dosing of the flock could lead to a reduction in reinfection and eventually eliminate the parasite altogether. In practice, the land continues to be infected with fluke eggs because apart from rabbits acting as efficient reservoir hosts of the fluke, not all farm animals capable of acting as sources of infection are treated (it is rare to find that cattle are dosed, even in areas

where disease in sheep is endemic) and furthermore, it is the practice of some farmers to buy in fresh stock regularly.

GRAZING MANAGEMENT

The aim is to prevent the passing of fluke eggs on to areas where the snails live, and to limit the acquisition of infection at the most dangerous times of the year.

The habitat of the vector snail is often limited to comparatively restricted areas on the farm and it may be possible to keep stock away from dangerous areas, either permanently or at particular times of year. Most cercariae leave the snail and encyst on the herbage to form infective metacercariae during a fairly short period in early autumn, and therefore the period from the end of September until December is the most dangerous. Although metacercariae can live for very many months on herbage, natural processes tend to reduce their numbers as each week goes by. During this period of autumn and early winter stock must, as far as possible, be kept away from infection, grazing the drier parts of the farm.

Intelligent management, based on a full knowledge of the life history of the liver fluke can do much to control disease.

CONTROL OF THE SNAIL

By analogy with many other vector-transmitted diseases, control of the intermediate snail host is an attractive possibility. The use of molluscicides such as copper sulphate or sodium pentachlorophenate for the control of liver-fluke snails has often been advocated but seldom practised. Most informed opinion now considers that eradication of the snail is unlikely by using molluscicides even though in field trials an 80 or 90 per cent kill can often be demonstrated. Any permanent reduction in the population is extremely difficult because at any one time a proportion of the snail population is likely to be out of the water; snails have a characteristic habit of becoming immobile with the shell pressed against the mud in the drier part of the habitat; they can endure prolonged aestivation, and can move and recolonize with ease. However, strategic use of molluscicides, to reduce snail populations at critical times in the life history of the fluke may be extremely valuable. For example, an application of molluscicide in August can kill most of the snails with a mature liver-fluke infection within them, so that the enormous reduction in the exodus of parasites on to the pastures makes grazing virtually safe for the following winter.

DRAINAGE

Snails may be eradicated by the permanent destruction of their habitats and this can be achieved by drainage. At the same time environmental conditions will be made unsuitable for the other developmental stages of the fluke. Total eradication of the parasites can be ensured,

and in the present state of knowledge, drainage represents the only really permanent solution to the problem of fascioliasis.

Control in Practice

Several important factors need to be recognized when considering how far control measures have been used under practical conditions and how far the disease has been brought under control.

Farmers are normally not particularly aware of liver-fluke disease except in those years when it is unusually severe; so far as many sheep farmers are concerned the disease is only of significance in those years when large numbers of ewes die. Also, the recommended methods of control not only require some degree of special knowledge, but in some instances they are rather laborious to implement. Above all, these measures have to be put into operation annually in the expectation of disease which five years out of six never materializes.

Of the available methods of control, only one—the use of drugs against the liver fluke in the final host—has been practised at all widely. Very great benefit has resulted from the use of carbon-tetrachloride and hexachloroethane in spite of their lack of efficiency against the immature flukes. Present investigations, aimed at discovering more precisely the optimum doses to be used under different circumstances and the best times at which treatment should be given will, it is hoped, make chemotherapy more effective. Unfortunately, there is still no sign of a drug which would be fully effective against flukes less than five or six weeks old. This is a major disadvantage, not only because young flukes themselves can be highly pathogenic but also because it necessitates unreasonably frequent dosing.

Drainage, the radical method of control, must always be kept in mind, especially if the area to be drained is small. With the help of a government grant, the expense can usually be justified, for besides controlling the liver fluke, the benefit to the land will be considerable.

Unfortunately, in the areas of endemic fascioliasis, the problem is often more difficult. As might be deduced from a knowledge of the soil conditions necessary for the appearance of serious fascioliasis, drainage at farm level will not always solve the problem. For reasons of topography, rainfall and water supply, work on a much wider scale is needed where extensive areas of country are likely to be involved. The responsibility for drainage in large areas may be vested in a number of authorities and the administrative as well as the technical difficulties have to be considered. Unfortunately, the cost of the work may sometimes be prohibitive.

Improving Existing Control Methods

Work at Weybridge for the past few years has been concentrated on improving existing means of control. Field observation, combined with laboratory experimentation has enabled us to work out more exactly

the details of the life history of the fluke showing how long the parasite takes to complete its various developmental stages, both within the snail and on the pasture, and how the parasite responds to changes in the seasons or to alterations in environment. From this information it is possible to build up a picture of how epidemics arise in the field. Our main object has been to determine which particular circumstances lead to the occasional catastrophic outbreaks which result in heavy mortality among sheep.

A general association with wet summers has long been recognized and Ollerenshaw has been investigating more precisely the climatic factors which induce serious outbreaks, with the object of using purely meteorological data to predict the appearance of serious disease. Ability to anticipate the bad seasons enables the farmer to adopt measures which might be considered uneconomical if they had to be applied each year. Some success has already been attained in at least that part of Britain (Anglesey) where our field investigations have recently been concentrated and it is hoped in the future to extend the work to other parts of the country.

LIMITED RESPONSE TO 1958 WARNING

Following observations made earlier in 1958, a warning to farmers in North Wales of the imminence of a serious epidemic of liver fluke disease was issued in August (in time for preventive measures to be instituted), which was, of course, amply justified by the events of the following autumn and winter. It was unfortunate that on this occasion the response from farmers was very limited and it seems that very few carried out the recommended control measures. Perhaps this was because it was the first notice of its kind to be issued by the Ministry and there had been no very recent experience of heavy losses which might be expected to produce a good response in a subsequent year. Similar warnings in the future may be expected to produce more effect. Nevertheless, since general propaganda about the control of liver fluke disease had possibly not been fully effective in the past, a special Working Party was set up by the Ministry's Animal Health Division to take over this part of the work in Wales and to ensure that all the most recent information on the control of fascioliasis is readily available to the farmer.

Fascioliasis remains a difficult problem and in particular instances will remain so until a more satisfactory drug is produced or until effective drainage schemes can be completed. In the meantime, with our existing knowledge and the means of control that are available, our work is largely concentrated on improving those methods and spreading the knowledge more widely among farmers.

Progress of the Small Farmer Scheme in Cardiganshire

D. S. DOWNEY

National Agricultural Advisory Service, Cardiganshire

CARDIGANSHIRE stretches along the picturesque shore of Cardigan Bay for over 50 miles and extends some 20 miles inland into the central Cambrian mountains. There is only a narrow ribbon of coastal plain before the land rises sharply to a plateau of undulating upland which extends to the foothills of the mountains in the east.

The soils are derived mainly from Silurian shales and grits and are deficient in lime and phosphates. Rainfall increases from 35 in. on the coast to over 60 in. in the hills and as could be expected, the climate suits grass, which covers 80 per cent of the county.

The farms are generally small, and dairy farming with some store cattle and sheep is widespread, giving way to livestock rearing and sheep in the hills in the north and east.

The Small Farmer Scheme

When the conditions of the scheme became known, it was estimated that 710 holdings out of 5,200 in the county would be eligible. The White Paper "Assistance for Small Farmers" explains that "Many small farmers need to take special steps to adapt their methods, production and resources generally if their small farm businesses are to earn a satisfactory living for them". It goes on to say that "the Government through their advisory services have been placing increasing emphasis on the improvement of farm management on farms of all kinds. In the Government's view what is now needed is a special drive to encourage the smaller farmers to take advantage of modern knowledge and practice, supported by the provision of initial working capital to make such a drive effective."

Method of Approach

The scheme was announced in November, 1958, to come into operation in April, 1959, although applications could be received in January, 1959. Advantage was taken of this winter period to organize meetings throughout the county to acquaint farmers with the purpose and conditions of the scheme. The N.A.A.S. is primarily concerned with advising applicants on their farm business plans and although most farmers have sound ideas, these need to be welded into a long-term programme. To do this successfully, it is first of all necessary to examine the farm business as it stands and to try to discover its strong and weak points. Full farm management studies were not possible in the time, yet

uniformity of approach and reasonable thoroughness was essential. An abridged farm management study on the lines of the Drill Sheet brought into use in Wales was therefore agreed upon, thus attaining a reasonable speed with uniformity and fair accuracy in helping the farmer to establish his plan.

The District Advisory Officer must walk the farm to schedule the area of crops and grass, see the layout of the farm and acquaint himself of all physical details including stock, crops and machinery. During this time the farmer's proposals and farming preferences are discussed.

Back at the farm the District Advisory Officer records the physical details of crops and stock, calculates the standard man days requirement of the present business and assesses the amount of labour available for any modification. This sets the stage for the next important step. Since the main objective of the scheme is to increase the earning power of small farms it is essential to estimate the current net farm income of the business as it stands. An estimate of the profitability of each enterprise helps to decide which could be expanded profitably and which might be better curtailed or even eliminated. The District Advisory Officer can use the economic data collected to help the farmer formulate the objectives of his scheme. Every effort is made to show the possible effects on the farm business of various changes which might be possible with the available resources. Once the objectives are agreed upon, an estimate is made of the net farm income at the completion of the plan, to see if it meets the requirements of the scheme. Lastly, the various means of achieving the objectives, e.g., organizing and phasing of drainage, field cropping, provision of stock, buildings and other capital requirements are worked out in detail and recorded to give a plan of improvement over the chosen period.

Farm Business Plan

Preparing plans is a time-consuming task dependent on many factors, only some of which are in the control of the advisory service, but with practice the speed of work has increased materially since the scheme started. Nearly two-thirds of the applications expected have been received and dealt with, and some generalizations about the programmes submitted can be made for the three systems of farming involved, namely, dairying, mixed farming and livestock rearing.

Dairy Farming

It is the very small dairy farm which qualifies for assistance in the county. Both tradition and the numbers and type of buildings available have a bearing on the numbers of cattle kept. Most farmers rear their own replacements and, where cowshed accommodation is limited, a few store cattle are reared for sale. In practically all the cases dealt with, economic analysis showed that it would be desirable to increase the

output of milk sold per cow and to increase the intensity of stocking. Therefore the kind of programme submitted is one to improve the herd and its production by better management and increasing the number of cows. The cropping programme and husbandry work is designed to increase the productivity of the land for feeding a dairy herd with economic milk production. On some farms, especially the smaller ones, the number of followers has been reduced to allow room for more cows. The pig and poultry enterprises have usually been left at their existing level.

Mixed Farming

The "mixed" farming holdings which qualify for assistance under the scheme are traditionally livestock rearing farms which have gone over to the production of some milk. They carry a small flock of sheep, perhaps a breeding sow, and always some poultry. The buildings frequently need modernizing and are often inadequate for the existing stock.

To increase the earning power of such a business it is necessary to increase the output of commodities which have a relatively high cash value, such as milk. Generally, the schemes evolved have been designed to intensify the dairy enterprise, and again the objectives of the farm business plans are (1) to improve the herd, (2) increase the number of cows, (3) increase milk production per cow by better management, (4) rear herd replacements, and (5) maintain existing subsidiary enterprises. The cropping and husbandry programmes follow the pattern of the true dairy farm.

Livestock Rearing

Livestock rearing farms present a different problem. Normally, these holdings have a small area of fairly good land around the homestead, a relatively large area of steep enclosed sheep pasture and, frequently, grazing rights on the open hill as well. Since the size of the ewe flock is determined by the amount of summer grazing available, any increase in the size of the flock must be accompanied by increased pasture production. It is difficult to improve the steep enclosed sheep pastures and impracticable to improve the open hill. The traditional cattle rearing system is one where calves are reared and sold as strong stores after spending two winters on the farm.

It is difficult, therefore, to devise a plan which would result in sufficient improvement to justify a scheme, since the only objectives could be a small increase in the ewe flock, together with an increase in the number of breeding cows, partly by selling weaned calves and partly by improving the production of grass and crops from the better land.

An analysis of a sample of schemes from each system of farming shows that the return from the additional capital invested is likely to

be greatest from pure dairy farms, but as the small "mixed" farm swings more to dairying, the anticipated return compares favourably with the dairy farms. The return from the additional capital invested on the livestock rearing farms is likely to be much less than that from the other systems.

Farming System	Acres		Net Farm Income		Increase as % of Grant	Total Grant
	Crops and Grass	Rough	Present	End of Plan		
			£	£		£
Dairying . .	45·2	4·6	581	829	36·9	805
Mixed . .	49·4	10·4	540	817	34.1	860
Livestock Rearing	58·5	47·7	551	726	20·0	872

Effect of Future Work of N.A.A.S.

Now that the bulk of the applications have been dealt with, the problems are more apparent. Most people knew that there was a considerable difference between milk sales per cow from farm to farm, but few realized that the variation was so great. In a random sample of 30 schemes the milk sales per cow have varied between £55 on the lowest output mixed farms and £150 on the best dairy farms. The purchased food input has varied from 3–23 cwt and high inputs of food have not always been associated with high outputs of milk.

Obviously, there is room for much improvement in efficiency of milk production and great scope for advice on cowmanship and on the improvement of dairy herds.

Up until 20 years ago few people sold milk and the traditional system of farming was one of store cattle production with small subsidiary enterprises of pigs and poultry. Field cropping was tied to the demands of store stock production and the provision of some food to help maintain the family. Many small farmers, having switched over to milk production, have maintained a relatively large store cattle enterprise and have stuck to a cropping system similar to that associated with store cattle production. They have thus seen the need to break away from tradition, but have been unable to take the necessary steps to do so. They are glad of the help of the farm business plans which will push them forward into a more profitable system of farming, particularly since the stages of development have been carefully planned over a period of years.

The number and type of buildings are invariably inadequate. Most of the farms are owner-occupied and their gross output over the years and even generations has been insufficient to accumulate capital to

make good this deficiency. Capital and advice on layouts of new farm buildings to suit the requirements of the small farm is therefore needed. Obviously, these "Small Farmer Scheme" programmes will need to be backed up with sound advice if the best use is to be made of all available resources. In the county the N.A.A.S. has under way an advisory programme designed to provide the knowledge to help farmers to improve their management in aspects which are at present deficient. The Livestock Husbandry Officer is advising individual farmers on methods of herd improvement, and demonstrations to show these points in an economic setting are being organized. A series of lectures on feeding and management of the dairy cow, on milking machine management and milking routines are being held in each district, and farms with a low level of production are being selected for individual advice.

A two-day course in cowmanship has already been held, in conjunction with the local education authority, at Canolfan Addysg, Felinfach (the County Farmers' Education Centre). The main concern at the time of writing is whether the rate at which new applications will be received in the immediate future will allow time for the limited staff available to put this programme fully into operation.

The scheme has been welcomed and well taken up by small farmers, a number of whom have already completed their first year's programmes and have drawn their grants. Its introduction has meant a heavy work load for N.A.A.S. Officers and it is clear that their work with the small farmer is only beginning.

New problems have already come to light; old ones have become more obvious and, no doubt, many more new ones have yet to be encountered.

Sampling Surveys in Agriculture

D. A. BOYD

Rothamsted Experimental Station, Harpenden

IF A SURVEY is proposed, the first question to be considered is whether the information sought is of a kind that can validly be given by a survey rather than by experiment. When faced with demands for an investigation needing much detailed research, it is tempting to fall back on a survey, if only to show that something is being done. In fact, the survey and experimental methods are often complementary; they are rarely interchangeable.

The principal use of surveys is to describe an existing situation; to discover, for example, the extent of certain diseases in dairy herds, how much fertilizer is being applied to a particular crop, or the relative popularity of the different varieties of cereal. The extent to which

changes are taking place from year to year can also be assessed by repeating the survey. At the same time it will generally be possible to make useful statements on the extent to which any factor under investigation is associated with other aspects of husbandry. Thus it can be shown how fertilizer practice varies according to the previous year's cropping and manuring, how manuring of combine-drilled crops differs from that of crops for which the fertilizer is broadcast, and how practice on different farms and in different districts varies. It is not, however, possible to obtain from survey data any worthwhile estimate of the effect of fertilizer on the yields of crops to which it is applied. It is important to understand why this is so, because survey data are often misused in this way—not least by agricultural economists.

MISUSE OF SURVEY DATA

Variations in yield from field to field and from farm to farm are due to many factors, of which fertilizer practice is only one, and often not the most important. Moreover, some of these factors are inter-related in such a way that it would be difficult to disentangle their separate effects with any certainty, whereas others, like quality of management, can scarcely be measured at all. Arable farmers who use fertilizers liberally also tend to use modern varieties, sound rotations, appropriate and timely cultivations, so a graph of fertilizer use against yield per acre usually gives a much exaggerated impression of the effect of fertilizer; on the other hand, survey data greatly underestimate the effect of farmyard manure on such crops as potatoes, because manure is mainly applied by non-specialist growers.

Survey Methods

Having decided that the objectives are such as can reasonably be achieved by survey methods, several different procedures are possible, depending upon the information needed and the resources available. The two main alternatives are a postal survey or one by personal visit. Clearly, if it is a question of investigating the extent of some pest or disease requiring expert diagnosis, there is no alternative to the personal visit, but for some enquiries the postal survey may be practicable; it has the advantages of speed and cheapness. Speed is often important where action is to be taken as a result of the survey, and it is feasible for the main results of a postal survey to be available within a few weeks.

POSTAL SURVEYS—THEIR VALUE AND LIMITATIONS

Postal surveys made in recent years have demonstrated that this is a simple and economical method of obtaining information from farmers, but the type and amount of information obtainable at any one time is severely limited, and some degree of bias in the results can rarely be avoided. Probably the most important single factor responsible for success in such surveys is the choice of subject; it is obvious that a

worthwhile response will be obtained only when the questions are on a topic in which the farmers concerned are really interested, and when the enquiry is so timed that the subject is fresh in their minds. Whatever the subject, it is unwise to try to obtain too much information from any one set of replies; half-a-dozen straightforward questions requiring simple answers will usually be enough.

The reply-paid postcard enclosed with a short covering letter is usually the most successful form of approach; anything which involves extra effort from the respondent, even if it is only folding a sheet of paper and putting it in an envelope, is likely to reduce the number of replies. If possible the questionnaire should go out on its own, not with other literature, whether on a related subject or not. Generally speaking, the aim should be to attract a reply by return of post; once a questionnaire reaches the "pending" tray it stands every chance of ending up, a week or two later, in the waste paper basket.

Even in favourable circumstances, voluntary postal censuses and surveys do not usually produce replies from more than 75 per cent of recipients. Clearly a large proportion of non-responders cannot be compensated for simply by sending out more questionnaires, because those who reply cannot be regarded as entirely representative of those who do not reply; if many fail to reply the results may be so unrepresentative as to be worthless. Exceptionally, it may be worth while to check on the extent of this bias by personal visits to a proportion of those not replying, but this substantially increases the cost and reduces the speed of the survey. A very interesting postal survey including a follow-up of this kind has been made in Cambridgeshire by L. W. Osborne.

SURVEYS BASED ON PERSONAL VISITS

In view of the limitations of postal surveys, most agricultural surveys are bound to be based on a personal visit to farms. Usually this means organizing a special survey of a properly selected sample of farms which can be expensive in both time and money. If the full costs of officers' time and travelling must be charged against the survey, the cost is unlikely to be less than £5 per farm but sometimes it is possible to save much of this expense by making use of the routine visits of a district officer, or of other N.A.A.S. officers; very often quite useful information of an exploratory nature can be obtained in this way.

However, a survey of this kind cannot claim to cover anything approaching a random sample of farms; the more progressive farmers tend to seek N.A.A.S. advice, and they can be expected to be over-represented in the sample of farms visited; on the other hand, there will also be a tendency for the visits to be made to farms with problems arising from livestock losses or crop failures. Compared with a random sample, therefore, there will be an undue proportion of the extremes; nor will there be any guarantee that, in any particular group of farms visited, these two opposing tendencies will cancel out. When fully reliable and objective data are required, the sample of farms to be

visited must be truly representative of the district or county to which it refers.

Representative Samples for Reliable Data

In most surveys, whether by postal enquiry or personal visit, it is impracticable and, indeed, quite unnecessary to obtain information from the entire population in which one is interested, and numbers must be reduced to practicable limits by some form of sampling. The number of farms or fields to be included in the sample will depend upon what variability can be expected in the data obtained, on the degree of precision required in the results and on the cost of obtaining additional data. At least 100 or 200 replies could be sought from a postal survey, whereas for personal visits a sample of 40–60 farms is often the practicable limit. In this country a survey of fewer than 20–25 farms would rarely be worth the labour, because of the wide variation in conditions from farm to farm, even in relatively homogeneous districts or counties.

A certain amount of office work is required to draw up a proper sample of farms, and unfortunately there is a temptation to try to cut this out to get on with the job—an impetuousness which rarely pays. A mere half-day in the office can easily save ten days of fieldwork as well as leading to more reliable results. Sampling procedures can be particularly simple for members of the N.A.A.S., since they have access to the names and addresses of farmers and the acreages farmed; alternative sampling methods, such as the location of points on a map, are very much more tedious.

Sampling Methods

In the simplest form of sample it is sufficient to take every n^{th} farm from a list of all farms in a district or county, or, where there is a file for each farm, to select every n^{th} file. Thus, if there are 6,000 farms in a county and the sample must be limited to 50 farms, we can take every 120th farm. (This fraction $\frac{1}{120}$ is known as the *sampling fraction*.) It is usual to choose the starting point at random, in this example between the 1st and 120th farm. In estimating any county total from the results of the 50 farms we will have to multiply up by the reciprocal of the sampling fraction (i.e., by $\frac{120}{1}$); thus if the total acreage strip-grazed on the 50 sampled farms was 400 acres, our estimate of the total acreage strip-grazed in the county as a whole would be $400 \times 120 = 4{,}800$ acres.

This form of sampling is known as *systematic sampling*. It is easier to draw such a sample than to select each farm independently, using a series of random numbers. When the farms are already arranged by parishes, an individual systematic sample is more likely to give adequate representation to the different parts of a county or district than is a random sample of the same size. In other respects the random and systematic samples are similar.

STRATIFICATION

The method of sampling just described is very simple but it may have some practical disadvantages. In many districts there are far more small than large farms, although the combined acreage on the large farms may be equal to or greater than the combined acreage on the small farms. Suppose that half the land in a district is to be found in farms of 200 acres and over, but that this acreage is controlled by only one-fifth of the farmers, then in a random sample of 50 farms there will be only about 10 of 200 acres and over, against 40 under 200 acres. When the interest is in acres rather than farmers, a fieldman's time could be used more economically in visiting a greater proportion of the larger farms.

In the above example, since farms of over 200 acres represent half the total acreage, they might reasonably be allocated about half the farm visits. To achieve this the farms in the list must be grouped according to whether their acreage is under or over 200; such groups are known as *strata*. An alternative procedure would be to draw a sample without taking account of acreage, but striking out from the sample every other farm under 200 acres. In analysing the results of any stratified sample it is usually necessary to present *raised* figures, i.e., to multiply up the results for farms in each stratum by the reciprocal of the sampling fraction appropriate to the stratum.

SURVEY OF FERTILIZER PRACTICE

The foregoing example considered only two strata, but 3, 4 or 5 strata are commonly adopted. Thus for the *Survey of Fertilizer Practice* we have four size groups, 5–50, 51–150, 151–300, and over 300 acres crops and grass. In this survey, while the sampling fractions are normally chosen to ensure a higher representation of the larger farms in the sample than is found in the country as a whole, this is not the only factor considered, as it is desirable to ensure that each size group is adequately represented, with a view to comparing the manuring of farms of different size. Thus, apart from increasing the accuracy of results for the country as a whole, differences between the size groups may be of interest in their own right.

In deciding on sampling fractions it should also be borne in mind that there is a tendency for more of the small farms in a sample to become "casualties", i.e., on such farms the farmer may only work part-time on the holding and so be difficult to find; if he is ill or away from home, there is often no one else able to supply the information.

There are alternative procedures which have advantages in certain circumstances, such as sampling strictly proportional to size and sampling from intersections of a grid on a map, or from a line or lines across a map; a full description of these methods is given in Chapter 3 of a standard work of reference by F. Yates.*

* *Sampling Methods for Censuses and Surveys*, 2nd edition, 1953. Griffin, London.

SUB-SAMPLING PROCEDURES SAVE TIME

It is often convenient to collect certain items of information from only a sub-sample of the farms visited. Thus, in a recent survey carried out by the Potato Marketing Board and covering many aspects of potato-growing, the laborious estimations of crop yield were confined to a sub-sample of only one-tenth of the original sample of farms. Again, as supplementary information for the *Survey of Fertilizer Practice*, a soil sample is obtained from one arable and one or two grass fields chosen with the help of random numbers from all the arable and grass fields on each farm visited. Sub-sampling procedures of this kind are particularly useful where much of the variability comes from differences between farms rather than within a farm, and where the collection of the data is very time-consuming, as in the examples quoted.

Collecting the Information

Whatever the survey, it is important that the objects should be clearly defined at the outset and that they should be explained to the respondents. Where the survey is by personal visit, the surveyors must both understand and be in sympathy with these objects. Unless there is close personal contact between the organizer of the survey and the fieldman, a separate set of carefully worded instructions on procedure in the field is essential. As far as possible detailed instructions to surveyors should be kept off the record sheets.

It is sometimes difficult to persuade fieldmen to read instructions, but the organizer of the survey should not proceed until he is confident that the instructions have been read and understood. For larger surveys, a preliminary trial-run, in which the surveyors are brought together on one or two farms, will go a long way to ensuring that each man understands the procedure for the survey, and will also permit some calibration of eye-estimates, if necessary. Even when these precautions have been taken, the organizer of a survey will be unwise if he relaxes his vigilance once the survey is under way. He should arrange to see the first half-dozen completed survey forms from each fieldman to make sure that the survey procedure has been fully understood.

The surveyor must always be on the watch for any source of bias in the survey data. For example, if a farmer is not on the telephone and never seems to be at home, it is tempting to substitute the name of a more accessible farmer in the sample. However, with only a quite small proportion of such rejects the sample may no longer be representative of the district surveyed. In surveys of crop or animal husbandry it is often important that the information collected covers the *whole* of the crops or *all* the animals in the herd which is the subject of the survey (or else a proper sub-sample). It is easy to overlook one or two outlying fields or a few dry cows; their omission can appreciably affect the reliability of the data. A map of the farm and a check against the farmer's official returns will help to avoid this trouble.

The form of the interview and phrasing of the questions can appreciably affect the answers obtained; in particular, it is very easy for the interviewer to suggest answers to the farmer, especially if the interviewer is in a hurry and the farmer a bit slow to collect his thoughts. There are, of course, some subjects on which it is virtually impossible to obtain information free from bias; thus one cannot expect entirely frank answers to questions affecting a farmer's prestige or financial position.

THE QUESTIONNAIRE

It is a common failing to make the questionnaire too long and complicated; this is especially to be guarded against where the survey is being designed by a group of people each with differing interests. Travelling time and finding the farmer represent a large part of the cost of surveys, and it is tempting, once on the premises, to gather as much data as possible; but anyone who presents a farmer with a questionnaire covering half-a-dozen pages of foolscap should not be surprised if, after the first page or two, his victim suddenly remembers an important engagement! It is important not to ask for a great deal of background information on crop acreage and stock numbers, especially at the beginning of the questionnaire; frequently these can be obtained from other sources and filled in before or after the visit if they are essential to the survey. Experience shows that the most accurate information is obtained in the first half-hour or so of the interview; this is when the most important questions should be asked. After an hour or so, it is certain that both the farmer's and the surveyor's interest will be on the wane, and two hours are considered an absolute maximum for any interview.

Although the questionnaire must not be overloaded, it is important not to leave out some really important question. One way of avoiding such omissions is to fill in the proposed questionnaire with "dummy" answers to get some idea of how to analyse the results. Better still, it may be feasible to try out the questionnaire on one or two farmer friends; very often a practical test of this kind will be found to be worth any amount of armchair discussion.

The layout of the questionnaire and the method of reproducing the forms will depend very much on the nature and size of the survey and whether or not the forms will have to stand up to an outdoor life. If at all possible, copying the original survey forms on to nice clean sheets or cards should be avoided; there is no more fertile source of errors than the typing pool's rendering of hastily-written pencil figures. For the small local survey it will probably suffice to run off sufficient forms on the office duplicator, but when more than a few hundred are needed, the use of printed cards should be seriously considered. Printing is particularly desirable for postal surveys, but even for surveys by personal visits, the extra cost will be a small part of the total cost of the survey, and the gain in neatness and legibility may be well worth while.

In many modern surveys the information is recorded on edge-punched cards. At Rothamsted a card about double the size of an ordinary postcard with about 100 marginal holes is normally used; larger cards are available if required. The cards are sorted quickly and efficiently by means of an ordinary steel knitting needle, and the time saved compared with hand sorting can be very great. The cards can be printed by the manufacturers or by the local printer and, with care in designing the layout, a very large amount of information can be recorded in this way. Because the margins must be kept intact, cards are not very suitable for outdoor use in wind and rain, but have given excellent service for many years in surveys like the *Survey of Fertilizer Practice*, where the interview normally takes place in the farmhouse or farm office.

For larger surveys with a thousand or more individual returns the information is usually recorded on forms and the coded data punched on Hollerith cards for mechanical sorting, counting and tabulation; in the last year or two, however, experience at Rothamsted has shown that the electronic computor can deal with large amounts of survey material, and methods for handling such data are being developed as rapidly as possible.

Laboratory Techniques for Assessing Nitrogen Requirements of Crops

J. WEBBER

National Agricultural Advisory Service, Yorks/Lancs Region

TODAY, the soil chemist has at his command laboratory tests to help him in formulating advice on the use of most of the nutrients required by crops. Tests for "available" phosphorus and potassium have long been used, and more recently it has become general practice to examine soils, when necessary, for their content of many other elements. In the use of nitrogen, however, no such assistance is available, and advice still has to be based on practical considerations such as cropping history, soil type, and so on. In the past, it was assumed that crops responded to nitrogen under almost all conditions, but with the generally higher level of manuring and the wider acceptance of systems such as ley farming, exceptions to this rule are becoming more numerous and there is a growing need for suitable soil tests for nitrogen.

Difficulties in Designing Tests

Because of the difficulty of devising a suitable technique, there is no generally acceptable test for nitrogen. The simplest and most obvious approach is to determine the total nitrogen present. Some workers using a limited range of soils have claimed a good correlation between total content and the release of nitrogen for crops, but the method is not applicable to the more varied conditions met in advisory work.

Another approach is to estimate that fraction of the total nitrogen "available" for crops. The failure of this method lies in the fact that whereas nitrogen is absorbed by plants in the form of nitrate and, to a lesser extent, ammonia, the element is found in the soil in much more complex forms. Nor is it yet known with any certainty which compounds in the soil break down most easily to release nitrogen for plant growth.

A further possible method is the determination of mineral nitrogen (nitrate and ammonium); it has been known since the days of Liebig that non-leguminous plants obtain most, if not all their nitrogen in these simple forms. The amount of mineral nitrogen in a soil fluctuates widely during the course of the year, and is influenced by so many external factors that its estimation has been thought by most workers to be of little value. Better results have been obtained by investigators who have measured the rate of mineralization of nitrogen under controlled conditions. As these have usually been kept as near optimum as possible, the results have provided information on the potential power of the soil to provide mineral nitrogen. In the field, factors such as poor structure, heavy rainfall and the like can seriously reduce mineralization and affect crop growth, but despite this very good correlations between the laboratory estimates and field responses have sometimes been obtained.

Total Nitrogen

Some American workers have found close relationships between total soil nitrogen and crop yields or the soil's capacity to provide nitrogen. Fraps and Sterges [1] summarizing the results of many years' work in Texas concluded that in general a soil's nitrification capacity was related to its total nitrogen content, but under field conditions factors such as soil acidity, poor structure or lack of other nutrients could upset the relationship. Carpenter *et al.* [2] showed that in a long-term experiment the yield of wheat was closely correlated with the nitrogen content of the surface soil.

Other workers, notably Gainey *et al.* [3] came to the opposite conclusion. They compared areas of good and poor growth of wheat in the same field at a large number of centres and found that while total nitrogen contents were similar, the good areas were able to mineralize enough for satisfactory growth, while adjoining poor areas showed acute nitrogen deficiency. They concluded, as had Crowther and Mirchandani, [4] from a study of rotation experiments at Woburn that only a fraction

of the total nitrogen in a soil was active and able to contribute to crop growth.

In a recent extensive investigation Allison and Sterling [5] found for a single soil type used in a long-term experiment a very close correlation between total nitrogen and mineralization under laboratory conditions. Cooke and Cunningham [6] also found a general relationship between mineralizable and total nitrogen, but had insufficient data to relate either to crop responses to nitrogen.

Fractionation of Soil Nitrogen

The proportion of the total soil nitrogen mineralized and thus made available to crops in any one season is only 1–3 per cent (Bremner [7]). This acts as a natural safeguard against serious depletion of soil reserves but the actual amount made available, especially in fertile soils, is still very considerable.

Many nitrogenous compounds have been identified in small amounts in soil, but the most important groups are amino-acid polymers which Bremner [8] has shown to make up about 40 per cent of the total nitrogen, and amino-sugars which account for another 5–10 per cent [9]. The other half of the total nitrogen content is in forms which are resistant to chemical attack and whose constitution is unknown.

Winsor [10] concludes that much more work will be required before the mineralizable nitrogen in soils can be related to any definite constituent of soil organic matter, but suggests amino-acid nitrogen as a likely fraction in which to look. This agrees with the findings of Cornfield [11] that the proportion of protein nitrogen in soil tends to decrease under the influence of factors, such as cropping or lack of manuring, which reduce the total nitrogen content. Much remains to be done in this rather difficult field of study and in general the techniques necessary are not likely to be adaptable for routine advisory work.

Mineral Nitrogen

The amount of mineral nitrogen (nitrate plus ammonium) in a soil under field conditions fluctuates over a wide range during the year and Harmsen and van Schreven [12] in their review concluded that "the content of mineral nitrogen found at a given time does not provide helpful information about the need for nitrogen fertilization".

However, a recent paper by Cooke *et al.* [13] suggests that the soil nitrate content at the time of planting spring wheat and barley indicates the need or otherwise for nitrogen fertilizers. They followed the effects of weather conditions and fertilization on soil nitrate figures during the period March–June at nine sites. The fertilizers used—sulphate of ammonia, "Nitro-Chalk" and calcium nitrate—increased the amount of nitrate in the soil until mid-May when heavy rain and/or crop

growth reduced it to the level found in unfertilized plots on the same site. They found that on soils with nitrate nitrogen concentrations at sowing of 7 p.p.m. or less there were good responses to nitrogenous fertilizers.

In later papers [14, 15] the Rothamsted workers showed that losses of nitrate in summer from both heavy and light soils were mainly due to rapid uptake by crops, since only after persistent and prolonged rain did appreciable leaching occur. They also stressed [6] that determinations of nitrate on samples of very light soils or during the growing season were likely to be of little value.

Many workers have commented on the low ammonium and nitrate contents of soils under permanent grass. Richardson [16] showed that sulphate of ammonia was completely absorbed within 7–14 days of application and Cunningham and Cooke [14] also found that ryegrass took up inorganic nitrogen very rapidly. It is evident that determinations of mineral nitrogen on grassland soils will be of little value.

Work on arable soils is continuing both at Rothamsted and at some N.A.A.S. centres where determinations of ammonium and nitrate nitrogen are being carried out in connection with experiments using nitrogenous fertilizers.

Incubation Techniques

Many attempts have been made to relate the production of mineral nitrogen when a soil is incubated to the need of crops for nitrogenous fertilizers when grown on that soil. Harmsen and van Schreven [12] have summarized some of the earlier work, and have suggested that close correlations between results obtained by incubation and in the field can only be expected when a single soil type, climate zone and farming system are being considered. They also consider that seasonal differences are important and point out that incubation techniques cannot be applied to grassland and forest soils.

Harmsen and Lindenbergh [17] took soils which had previously been exhausted of mineral nitrogen by one or more crops of spinach, incubated them at 29°C and measured at intervals their content of water soluble nitrogen. They calculated the rate of mineralization, which they considered was affected by initial soluble nitrogen content, and found the results useful in advising on the requirements of land being reclaimed in 1945–7 after flooding with sea water.

More recently workers at the Iowa Agricultural Experiment Station have developed a method suitable for routine use [18, 19, 20, 21]. The soil, which was previously air dried, was leached free of nitrate, mixed with vermiculite to improve aeration and maintain soil moisture, and incubated at 35°C for two weeks. Very close correlations were obtained between the nitrate nitrogen produced and the responses of maize to nitrogenous fertilizers and a regression equation relating yield with

nitrogen dressing and nitrate produced was calculated. The relationship only held for maize grown after a cereal, and could not be applied in cases where crops were taken after leguminous meadows.

Since the technique was a simple one involving a single nitrate determination for each sample, other workers have tried it for different crops and soils. Cook *et al.* [22] also obtained good results in estimating the response of wheat to nitrogenous fertilizers on a number of different soils in Saskatchewan. The limiting nitrate-nitrogen figures below which responses to fertilizers could be expected were 50 p.p.m. in stubble fields and 40 p.p.m. in fallows. Eagle and Matthews [23] used a modified technique in which a layer of soil between two layers of vermiculite was incubated at 35°C for one week without previous leaching. They appreciated that drying and storage of samples could affect the results and kept the soil for two weeks in a moist state at 10°C before the test was carried out. Three years' results showed a good correlation between responses of wheat, oats and potatoes grown in Ontario and nitrate produced on incubation. The method could not be used for soils which had recently had dressings of bulky organic manures or crop residues.

The Iowa technique without the addition of vermiculite was also used by Saunder *et al.* [24] in S. Rhodesia. On poor structured soils, unduly high rates of nitrification were sometimes found, due to the better aeration and moisture conditions associated with the use of vermiculite. Unlike the American workers, they determined both ammonium and nitrate nitrogen, as in some of their soils the conversion to nitrate was not complete after two weeks' incubation. Good correlation ($r = +0{\cdot}83$) was obtained between total mineral nitrogen and the yields of maize and tobacco produced without nitrogen fertilization. There was also a general relationship between mineralization on incubation and response to nitrogen, but it was thought unlikely, because of varying climatic conditions, that it would be possible to relate them closely as was done for maize in Iowa by Hanway and Dumenil [2].

Kresge and Merkle [29] made an appraisal of different laboratory techniques including incubation, and concluded that although the results were helpful in evaluating soils or management systems, they were of questionable value in determining nitrogen requirements in any one year because of the numerous other factors which could affect responses to fertilizers.

Incubation techniques have also been used at Rothamsted by Cooke and Cunningham [6]. They used a temperature of 18°C and incubated soils for 30 days at 50 per cent of their water-holding capacity. The mineral nitrogen produced was about three times as great when the samples were air dried before incubating as compared with the freshly sampled moist soil, thus confirming the findings of many other workers.

For air-dried soils, both nitrate and total mineral nitrogen produced on incubation were approximately correlated with soil nitrate levels at the time of sampling in spring and with total nitrogen content. These

relationships were less satisfactory when data for freshly-taken soil samples were considered. In later work, Gasser [25] followed the levels of mineral nitrogen in the soil under winter wheat through the season and measured mineralization on incubation at intervals. His results showed that higher levels of mineralizable nitrogen were obtained in the period January–March after heavy rain in December than during the rest of the year.

Results of incubation of soils from experiments with leys at the Grassland Research Institute have also been reported [26, 27, 28]. The effects of treatment of 3-year leys on subsequent cropping with wheat and on mineralization of nitrogen on incubating soils for 20 days at 30°C were compared and the following figures are of interest.

Wheat Yields (cwt per acre)

	"Nitro-Chalk" (cwt per acre)				*Mean*
Treatment	0	4	8	16	
Frequent grazing	35·1	38·0	43·9	43·5	40·1
4 cuts, herbage removed	34·0	33·8	29·9	32·0	32·4
Compare with yield after 1 year seeds in 4-course rotation					26·9

Mineral Nitrogen produced on Incubation p.p.m.

	"Nitro-Chalk" (cwt per acre)				
Treatment	0	4	8	16	
Frequent grazing	50·8	53·8	55·2	70·2	57·4
4 cuts, herbage removed	40·1	43·0	39·9	45·2	42·2
Compare with mineral N after 1 year seeds in 4-course rotation					33·4

(The figures are means for ryegrass/clover and cocksfoot/clover leys.)

For all treatments in these experiments, the response of wheat to fertilizer nitrogen was closely correlated ($r = -0{\cdot}866$) with the nitrogen mineralized.

Conclusion

Incubation techniques appear to provide a useful guide to the need for nitrogen fertilization when applied to a limited range of conditions. Some of the closest relationships between laboratory figures and field responses have been obtained when working on soils of similar type such as might be found on Experimental Stations. Much more work will have to be done to be able to apply such methods to general advisory work, where a wide range of soils, types of farming, and even climate are found. The need to sample at particular times of the year and to avoid recent use of bulky organic materials, and the effect of season on responses to nitrogen have been stressed by various workers. However, the success obtained at some centres is an encouragement to further work. With the present high consumption of fertilizers, soil

fertility is being raised and the numbers of poor responses to nitrogen are likely to increase. There is hope that in future it will be possible to give some guidance to farmers on their need for nitrogen, and work now going on at some N.A.A.S. centres will help towards this end.

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Developments in Ensiling and Haymaking Methods

C. CULPIN

Chief Machinery Adviser, National Agricultural Advisory Service

THE IMPORTANCE of the efficient handling of materials on farms is rapidly becoming appreciated, not only by farmers but also by manufacturers and those responsible for research and development. Changes that have taken place in recent years, with the widespread use of pick-up balers and forage harvesters, are remarkable enough; but we are not anywhere near the end of developments. Many of the new handling practices originated in the U.S.A., where labour is scarcer and more expensive than in Britain. A survey of the latest trends in the U.S.A. is therefore worth while since it may reveal developments that are worth exploring here. As in Britain, labour saving is not the only thing that matters: quality considerations must be constantly borne in mind when new practices are studied.

Silos and Forage Harvesters

Silage-making in the U.S.A. is rather complicated by the importance of the maize crop. As a general rule, maize for silage must be chopped, and this helps to explain the continued popularity of the chopper-type forage harvester. There are, however, other reasons for this; one is that short-chopped silage is more easily handled mechanically. A good deal of research has been devoted to methods of handling chopped materials [1]. Reaction type and motorized distributors for filling circular silos from a blower have been developed, and with such devices the need for a man in the silo can be eliminated.

A short cut ($\frac{1}{2}$ in. or less) is best for many reasons [2]. Automatic filling of cylindrical structures with a short-chopped material results in a more uniform density and reduces the power requirement for the filling operation. In the field, moreover, the power requirement for cutting by a mower bar and chopping is low compared with that for machines of the flail type [3]. The chopped material ferments rapidly and uniformly, and losses of nutrients are relatively low. Blowers are the most popular equipment for filling tower silos, but flight-type elevators are also used.

Self-unloading waggons with a pair of chains and cross slats are now widely accepted in the U.S.A. Trailers used for "zero grazing" usually unload into a cross conveyor, beaters being incorporated to break up the wall of chopped herbage as it moves forward [4]. With such a cross conveyor it is easy to drive so that the conveyor is opposite the end of

the trough of a silage blower, and this results in completely fool-proof mechanical filling of tower silos.

MECHANIZED SILAGE FEEDING

For mechanical unloading and feeding of the silage, electrically operated top unloaders, working in conjunction with auger conveyors, are most popular. Bottom unloading in conjunction with the hermatically-sealed type of tower silo has the advantage of minimum loss of nutrients, and the possibility of adding more silage to the top before the silage at the bottom is used.

Studies on the use of electrically-operated top unloaders (Clay, Jamesway and Van Dale) in New York State [4] showed an average operating cost, including depreciation, of 177 dollars* per year at an estimated life of 10 years, and a capital cost of just over 1,000 dollars. Cost per ton naturally varied with annual use, but more than half of the 31 unloaders studied had operating costs within the range $\frac{1}{2}$–1 dollar per ton. Costs were below 1 dollar per ton for all but one of the unloaders that handled 200 tons or more annually. As with so many items of farm equipment, justification of purchase depends more on factors such as getting rid of a disagreeable and occasionally dangerous chore than on saving money.

Mechanical unloaders for chopped silage contained in stacks or clamps incorporate a tractor-mounted rotary device that bites into the silage face and throws the material on to a chain and flight elevator. This outfit is not widely used as at present it is so complex that it is suitable only for large-scale enterprises [5], and makes the tractor unavailable for other purposes.

ECONOMICS OF BUNKER AND TOWER SILOS

Mechanical handling of chopped silage in tower silos can be made highly efficient from a technical aspect, but there may be doubts about its economics. In Michigan, an economic study has recently been made [6], in which bunker silos were compared with both "conventional" towers and airtight towers, on the basis of (1) the production of 400 tons of silage on a 60-cow farm, (2) 800 tons on a 60-cow farm and (3) 1,500 tons of silage for a farm with 120 milking cows. Some of the assumptions made are as interesting as the final result, viz., that use of the conventional type of tower is cheapest in every case, and that a properly constructed bunker silo covered with polythene sheet is the most expensive of the three for 800 and 1,500 tons. The air-tight tower silo was given a life of 30 years, the concrete stave tower 25 years, and the bunker silo, made of timber on a concrete base, only 12 years. Allowance was made for the difference in nutrient losses between the different silos.

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* 1 dollar = 7*s*. 2*d*. approx.

Haymaking

Development of methods of packaging hay that will eliminate hand work is a subject on which progress is being made both in Britain and in the U.S.A. In Britain, one approach has been to use a bale sledge to form heaps of 16 bales which can be lifted by a specially modified buck-rake, and either loaded on to a trailer or carried on both front-loader and rear buckrake directly to the barn [7].

In the U.S.A. chief interest has been in methods that eliminate hand work by making packages that will flow to a certain extent [8]. For example, one manufacturer has developed a baler which makes square bales that are catapulted after delivery into a box-type trailer, in which the bales roll into position. Another manufacturer has introduced a bale-throwing attachment that is engine driven and employs two high-speed endless belts to propel the bales into the trailer. At the barn, a moving-bed trailer unloads the bales on to an elevator, which carries them into and along the top of the barn, dropping them at the desired point where, again, they roll into position.

FIELD FORAGE PELLETING MACHINES

Many manufacturers are interested in going a step further, and evolving a field machine that produces hay "pellets" or "wafers". These wafers which are usually about 2–4 in. in diameter, and about $\frac{1}{2}$ in. thick, are readily eaten by cattle. Unfortunately, the production of wafers from either long or chopped hay at present requires high pressures and about as much power as does the cubing or pelleting of meals [9 and 10]. Bulk densities of about 25–30 lb per cu.ft are usually being employed experimentally, at moisture contents of about 15 to 20 per cent. Experiments are also being made at higher moisture contents, but it is almost certain that wafers made from hay of over 20 per cent. m.c. will have to be dried.

There has been confusion concerning use of the term "pellet" for this type of hay package, and the more recently introduced term "wafer" seems more suitable, although Bruhn still prefers to use the term "pellet" [10]. Field forage pelleting machines cannot be expected to come on the market overnight, but as Bruhn remarks, a factor in favour of rapid development is that there is a demand for such a machine even before it exists.

ROLLER CRUSHERS TO SHORTEN THE FIELD-DRYING PERIOD

Much of the time spent on the hay crop goes into moving the crop while it is lying in the swath, and there is great interest in using machines that will reduce the number of field operations and shorten the drying period—whether the hay is to be field dried or barn dried. Fifteen American manufacturers are producing 23 different models of roller crushers, and it seems certain that so far as America is concerned, roller crushers have come to stay [10]. Some machines crush with

smooth steel rollers while others crimp the crop with corrugated rollers. Some of the latest machines have rubber rollers. Roller peripheral speeds are fairly high in relation to ground speed, so that the crop passes through in a thin layer. Crushing must be done within about 30 minutes of cutting to secure the maximum stem splitting effect and to avoid wrapping.

In American experiments, crushing has reduced the field drying times by up to 30–50 per cent in good drying conditions, and has often resulted in up to 10 per cent higher yield, due to saving more leaves and small stems. It should be noted, however, that the effects of crushing or crimping are very small in cloudy, humid, cool weather [10], such as we often experience in Britain.

The extra cost of using a hay conditioner of the roller crusher type in the United States has been estimated at $3\frac{1}{2}$ dollars per acre for 50 acres treated annually, $1\frac{3}{4}$ dollars for 125 acres and 1·3 dollars for 200 acres [11]. The authors consider it unlikely that the extra value of the hay will usually cover the "conditioning" cost at 50 acres treated annually, but consider the conditioner a sound investment at 200 acres annual use.

There seems little doubt that we shall be seeing more of roller crushers in Britain, although earlier experiments with less advanced machines showed that good tedders might suit our conditions better [13].

QUALITY CONTROL AS WELL AS SAVING LABOUR

It is evident that American farmers, like the British, are seeking quality control as well as a reduction in labour [14]. Hay crushers contribute something to quality, but leave the final operations to chance. Barn drying reduces weather hazards but is difficult to manage on a big scale. Bale throwers and field pelleters make little or no contribution to quality control. Good-quality feed is produced from wilted silage conserved in air-tight towers although there are the disadvantages of lack of control during field wilting and reliance on rather complex machines for collection and loading of the silo.

Now that American equipment can be more easily imported, a few enterprising British farmers are already trying out some of the more promising machines and systems. However, the remainder are looking for comparatively inexpensive improvements, and can afford to wait until British manufacturers have proved the equipment in our conditions.

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Horticultural Management

KEITH DEXTER

Ministry of Agriculture, Fisheries and Food

The Aims of Horticultural Management

THE AIMS of advisory work in horticultural management are to help growers to assess the efficiency and profitability of their businesses and to assist them in making decisions for increasing profits. Some people are beginning to adopt advisory techniques for horticulture that have long been familiar in agriculture; business analysis and budgeting are becoming more popular. But these procedures can only be used effectively in conjunction with adequate comparative standards of performance. So far, economic research has not supplied such comprehensive standards as those available for agriculture, but some comparative standards and budgeting data for use in horticulture can be obtained from published sources, and a list of references is included at the end of this review.

Effects of Uncertainty and Risk

From time to time it has been suggested that management data are of little use in horticulture because of the considerable uncertainty and risk arising from yearly fluctuations in yields and prices. Admittedly, in the face of uncertainty historical data are imperfect guides, but since growers have to make management decisions, any assistance that can be given in the form of comparative standards and budgeting data will always be helpful.

The incidence of uncertainty and risk in the vegetable sector of horticulture has been studied by S. R. Wragg [1]. He shows clearly how uncertainty and risk arise from variation in prices, yields and production. The results are well supported by useful statistical measures. The first part of the report is concerned with an analysis of total U.K. production of vegetables over the ten years 1947-48 to 1956-57. Production was taken as the quantity of crops fit for the market, output being the portion of production marketed plus the amount consumed on holdings. Acreage and production of vegetables declined over the first half of the period and then recovered slightly. The gap between production and output was much wider in years of high production than in years of low production, showing the market's inability to absorb sudden and substantial increases in production. There was no evidence to suggest that total imports of vegetables compensated for fluctuations in total home production. The report also suggested that the gap between retail vegetable prices and what the producer received was widening, especially over the first half of the period under review. On the other hand, the trend of wholesale vegetable prices showed a slowly accelerating rate of increase during the period. Fluctuations in prices corresponding with variations in output of vegetables showed that a smaller total return to the industry resulted from increased output. In other words, there was an inelastic demand for vegetables, and price decreases were not offset by increases in the quantities sold.

Important sources of uncertainty and risk were examined for a number of vegetable crops. Variations in yields per acre were found to be high enough to affect profits seriously, but price variations were generally greater than the variation in yields from year to year. There were also considerable differences in the yields, prices and values of output obtained by individual producers. Year-to-year variations in profits suggested that uncertainty and risk affected horticultural holdings to a far greater extent than livestock or dairy farms. Nevertheless, the varying achievements of individual horticultural producers showed that there were opportunities on many holdings for improved management practices which would raise profitability despite uncertainties of yields and prices.

Assessment and Improvement in Horticulture

Two other reports provide useful comparative data for the assessment of a holding's efficiency and profitability.

FINANCIAL RESULTS ON MARKET GARDENS

H. M. Cole [2] has summarized financial results for eleven market garden holdings in south Devon, Dorset and Cornwall covering the years 1952-53 to 1956-57. Glasshouse produce, flowers, soft and top fruit, vegetables and livestock, in that order of importance, contributed to total gross output from holdings using glass. Holdings without glass maintained the same order of contribution for the outdoor sources of revenue. Over the five years, the largest percentage increase contributing to gross output for the eleven holdings was from livestock, but this was mainly due to developments on two holdings. Outdoor flowers and vegetables, and glasshouse produce also showed increases, while top and soft fruit showed a decrease. On balance there was a slight increase in total vegetable acreage and total glass area. Three of the holdings, $\frac{1}{2}$–$13\frac{1}{2}$ acres in size, using glass and maintaining a roughly constant level of physical output, each gave a relatively high average net income, although each showed a large annual variation in net income of up to £1,000. Labour and fuel accounted for 44 and 16 per cent respectively of total costs on these holdings over the five years. During this period the minimum wage rose by 25 per cent and the cost of fuel rose by an even larger proportion. Another three holdings, 1–$3\frac{1}{2}$ acres in size and using glass, progressively improved their net incomes by reorganizing and expanding production. Their total gross output rose by 73 per cent against an increase in total costs of 44 per cent. Increased output was achieved without increase in the labour force.

Financial data from the eleven holdings suggested that those operating at low output levels were in the best position to improve production and offset increased costs. Introducing glass and livestock enterprises are means towards this end, but on all types of holding consideration should be given to substituting more profitable enterprises, adopting better growing methods and improving marketing practices. The material in the report enables useful comparisons to be made when analysing the financial results achieved by other growers on similar holdings.

COSTS AND RETURNS ON SOFT FRUIT HOLDINGS

A report by W. L. Hinton [3] examines the structure of costs and returns for ten specialized soft fruit holdings in the Newick area of East Sussex during the 1954-55 and 1955-56 cropping years. Three holdings with two acres or less were part-time businesses; the remainder with mainly 5–10 acres were more mechanized and provided full-time occupation. Soft fruit accounted for 85 per cent of the holdings' total income and acreage. Total soft fruit acreage for the sample was made

up of 31 per cent raspberries, 23 per cent gooseberries, 15 per cent strawberries, 12 per cent black currants and 10 per cent blackberries.

Capital requirements of establishing soft fruit were estimated at £700 per acre. Labour constituted two-thirds of total annual expenses at £200 per acre, and £100 of labour gave £150 net output. As the main item of expenditure, labour was important in determining the efficiency of soft fruit production, and two suggestions for improvements in labour use were made. Firstly, permanent labour can be more efficiently used by growing soft fruit crops that give a more extended picking season, thereby diminishing labour peaks and reducing casual labour. Blackberries fill this role and their high net return is an added point in their favour. Secondly, poultry-keeping was recommended to utilize any surplus labour on the holding.

Complete and Partial Budgeting

Following assessment of a holding's performance the question arises of how to make improvements. This calls for the use of planning techniques of which the best known are complete and partial budgeting.* The difference between the two is that in complete budgeting estimates are made of future costs and returns of the business as a whole, whereas in partial budgeting estimates are made of the changes in costs and returns from a part of the business.

TRENDS IN APPLE PRODUCTION

D. B. Wallace and A. J. Plaister [4] present budgeting data for determining the costs of apple production and, in the introduction, discuss recent trends in apple production.

In 1957, the acreage of apples in England and Wales had declined by 8,000 acres from the 1951 total—a result of reduced acreage in cider apples, culinary and less successful dessert varieties. Against this trend may be set a steady increase in "Cox" planting during the post-war years. "Bramley", the most popular culinary variety, showed a decline that was much less proportionately than the total of other culinary varieties. It was suggested that from 1958 onwards an increasing volume of the better dessert varieties will be coming forward, reaching a peak by 1965. These trends have led to an estimated 25 per cent increase in the availability of fresh apples over pre-war, even though imports have

* In recent years farm management has been applying the more formal linear programming technique. Theoretically it involves the same concepts as budgeting. It differs from the latter by using a systematic mathematical procedure for recommending a profit-maximizing or cost-minimizing combination of enterprises. This procedure is only warranted on complex planning problems, which the less formal budgeting approach cannot handle so well. For the simpler planning problems in horticulture and agriculture budgeting remains the most useful technique.

declined correspondingly to 60 per cent. Also it was thought that the home market could probably take 50 per cent more "Cox's" at present prices. Such an increase in demand might still leave some surplus production when this variety comes into peak supply.

In 1956 a survey was made of 13 dessert and 10 culinary orchards distributed throughout the 5 East Anglian Counties, to obtain information about costs of apple production. The costs obtained from the survey were added to costs of establishment and costs of storing, grading and packing published by other research centres. The resulting total costs of production for dessert apples were given as £97·5 per acre, and for culinary apples, £102·4 per acre, in addition to packing shed costs of 7*s*. 5*d*. and 4*s*. per marketed bushel, respectively. Spraying materials for both dessert and culinary apples were the most costly single item of expenditure at £23 per acre. Labour came next, with the greater share going on pruning. Equations were derived from total costs of production for determining the prices per bushel, at any given yield, that would be necessary to cover total costs and to give a £70 surplus per acre.

The material in this report is presented in a form very suitable for the preparation of budgets. If current prices are substituted for the 1956 prices used in the report, then budgets may be prepared for either the long-term problems of establishing new orchards or the shorter-term problems associated with the annual costs and returns from an orchard. The report as a whole is recommended to growers and advisers in horticulture.

These recent economic reports focus attention on the importance of business analysis and budgeting in horticultural management. The list following the references includes other publications of interest and value in horticultural management advisory work.

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Regional Note

A Survey of Cattle Rearing in the Yorkshire and Lancashire Region

N. F. MCCANN*

National Agricultural Advisory Service, East Midlands Region

A DISCUSSION on the oft-repeated assertion that young cattle are badly reared, particularly in dairying areas, was the germ which developed into a survey to find out how well young cattle are reared up to two years of age. No written information could be found, other than a report published ten years ago† by Dr. F. W. Withers on mortality in calves, so data were collected on births, deaths, illness, feeding, housing and, finally, the condition of the young animals. Five areas within the Region were chosen, two in the rearing areas of North Lancashire and the West Riding, two in the dairying areas on either side of the Pennines in South-East Lancashire and South-West Yorkshire respectively and the fifth in the Yorkshire Wolds.

CALVES UP TO SIX MONTHS OLD (See Table 1 opposite)

(a) Mortality

Wide variations between the areas in the percentage of deaths up to six months of age are probably due, in the case of male calves, to the facts that, in the areas rearing dairy replacements, the male calves are not kept more than a few days, while in the East Riding the many purchased calves may have been bought too young and suffered too drastic a change of diet.

It is interesting to note that the figures for stillbirths and deaths differ markedly from those which Dr. Withers reported and which were taken from selected dairy herds over the period 1946–48. (See Table 2 opposite.)

Dr. Withers reported a marked fall in pre-natal losses between 1936 and 1948 and the further improvement since then may be due to the increased use of S19 vaccine and advances in the treatment of such diseases as vibrio foetus and trichomoniasis. Deaths up to six months

* Mr. McCann was responsible for this survey whilst serving as Deputy Regional Director, Yorks and Lancs Region.

† Mortality Rates and Disease Incidence in Cattle. *British Veterinary Journal*, vols. 108 and 109.

Table 1

Births, Purchases, and Deaths

Area	Births								Position at Six Months Old								Total Losses All Calves	
	Total		Live		Dead		Deaths		Purchases		Live Births and Purchases		Died		Deaths			
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	No.	%
							per cent								*per cent*			
Lancs. (North) . .	585	513	553	501	32	12	5·5	2·3	6	46	559	547	2	6	0·4	1·1	52	4·5
W.R. (Dales) . . .	366	399	355	386	11	13	3·0	3·4	56	56	411	442	11	4	2·7	0·9	39	4·4
W.R. (Indust.) . .	382	383	366	372	16	11	4·2	2·9	95	56	461	428	22	8	4·8	1·9	57	6·2
Lancs. (Pennines) . .	239	230	230	220	9	10	3·8	4·3	8	52	238	272	2	4	0·8	1·5	25	4·7
E.R. (Wolds) . . .	394	426	382	415	12	11	3·0	2·6	499	72	881	487	63	30	7·2	6·2	116	8·3
Total . . .	1,966	1,951	1,886	1,894	80	57	4·0	2·9	664	282	2,550	2,176	100	52	3·9	2·4	289	5·9

Table 2

Comparison of Two Surveys

	Total Births	Born Dead	%	Live Calves		Purchased		Total Calves		Died up to 6 months		%		Total Births and Purchases	Total Deaths	%
				M.	F.	M.	F.	M.	F.	M.	F.	M.	F.			
Withers	9,327	607	6·5	4,384	4,336	17	44	4,401	4,380	147	322	3·3	7·4	9,388	1,076	11·5
Y. & L.	3,917	137	3·5	1,886	1,894	664	282	2,550	2,176	100	52	3·9	2·4	4,863	289	5·9

of age show a striking improvement in female calves and the lack of improvement amongst male calves may be due to the fact that Dr. Withers was dealing exclusively with dairy herds where the male calves were sold at an early age. The overall fall in losses of nearly 50 per cent show that there has been a definite improvement in livestock management during the last ten years.

Of the 152 calves that died before reaching the age of six months, 88 were home-bred and 64 purchased. "Scour" was the commonest cause of death, and 54 of the 64 purchased calves were victims of this affliction. Ten home-bred calves died of poisoning, usually lead—which seems an unnecessarily high figure—and 22 home-bred calves died of a navel infection, 21 of them on one farm. A veterinary surgeon attended to the illnesses of about two-thirds of the calves that died.

(b) Management

Various questions were asked concerning breeding, method of rearing and incidental treatment. On most farms the majority of calves were born in the autumn and by far the greatest number were reared on the bucket. There was no general agreement about the right age or method for castration but there was a trend towards the use of rubber rings. Dressing the calves' navels was not routine practice and the use of medicinal drenches for newly-purchased calves was not common.

Dehorning practice presented an interesting picture. In the areas where cattle are reared for sale, dehorning was obviously spreading: in the areas where calves are reared for dairy herd replacement there was very little dehorning, although where calves were intended for fattening, dehorning was common. Thus, in the East Riding, 44 per cent of the farmers dehorn their calves against an average of 18 per cent for the other four areas.

(c) Feeding

As might be expected, in the few herds where single or multiple suckling was carried out, there was no standard practice. In the hand-reared herds all farmers considered the provision of colostrum to be important and hardly any calves had less than three days of colostrum feeding.

The next point concerned the provision of fresh milk. In the rearing areas of North Lancashire and the Yorkshire Dales ample milk was made available. In the West Riding industrial area no trend emerged; some farms relied entirely on milk substitute and others went to the extreme of lavish feeding with milk. Although milk is the predominant source of farm income in the area, the calves were given an adequate supply of milk in East Lancashire. East Riding, farmers, apart from the few rearing baby beef, finished with milk feeding as soon as possible and kept the amount of milk to a minimum.

The wide variations in the amount of milk fed to the calves were to some extent compensated for by feeding with milk substitute: the East

Lancashire area was the only one where a minority of farmers used it. This commenced usually during the first week of life and continued on most farms for at least two months. It was supplemented or replaced by the feeding of other concentrates, and, whereas practically every farmer feeding milk substitute used a proprietary mixture, much greater latitude was given to mixing a concentrate supplement for the calves. This was particularly noticeable in the East Riding, where ample supplies of home-grown grain were available and it was apparent that the availability of home-grown grain was coupled with a tendency to more generous feeding.

Questions were asked about roughages and the provision of water. The general practice was to supply hay as soon as the calves would eat it and about two-thirds of the farmers provided a constant supply of water, other than from buckets, during the first two months of life, nearly all starting in the first month. The type and quality of roughage fed to calves up to six months old varied according to local resources and the ultimate destination of the calves.

In the traditional rearing areas of North Lancashire and the Dales in the West Riding, a conscious effort seems to have been made to give the calves good-quality hay. On about half the farms the quality of hay fed to the calves was described as "good" and on only 7 of the 206 farms was the hay designated "poor". All but 13 of the 206 farmers fed concentrates, mostly proprietary, to the calves between three and six months of age. Seventy per cent of the calves took all their solid food as hay and concentrates. Silage, although in common use for dairy cows, was fed to calves on less than four per cent of the farms.

CATTLE 6–12 MONTHS OLD

(*a*) *Winter Feeding*

Not all farmers had cattle of this age during the winter, but 181 reports were given of winter feeding in this age group. Of the 181 farmers reporting, 114 fed hay as the only roughage. In the North Lancashire area over 40 per cent of the farmers fed no concentrates and relied entirely on hay for wintering the young cattle. In the Yorkshire Dales, only 2 out of 30 farmers fed no concentrates.

(*b*) *Grazing*

The calves born in the autumn and, consequently, out at grass for this period of their lives, nearly all had a full summer's grazing and rather more than half received a concentrate supplement. Of 178 reports on the quality of grazing, 81 were reported as "good", 73 as "moderate" and 24 as "poor".

CATTLE 12–18 MONTHS OLD

(*a*) *Winter Feeding*

Compared with the younger cattle, there was a slight tendency to give a little more varied diet of roughage to this age group. Concentrate

feeding was much less common and proprietary foods were outnumbered by home mixings. Naturally, when they were used, the allowances of concentrates were much higher than for the younger group. The figures suggest a sharp cleavage of opinion about concentrate feeding: one group of farmers seemed to consider that roughages are enough for the yearlings, the other that additional "cake" should supplement the roughages. This may have been no more than a reflection of intention, the store dairy cattle being slightly restricted and the fattening cattle being kept in a thriving condition.

(b) Grazing

Of 167 reports on grazing for this age group, only 11 showed supplementary concentrate feeding. The grazing was classed as "good" on 67 farms, as "moderate" on 67 farms, and as "poor" on 30 farms (3 of the reports made no reference to quality). There is a clear tendency for the quality of grazing offered to these older animals to be lower than that provided for the younger ones.

CATTLE 18 MONTHS–2 YEARS OLD

The trends in the previous age group were continued. Thus, in the traditional rearing areas only 15 out of 74 farms fed concentrates whereas in the fattening area concentrates were fed on 46 out of 61 farms. This reflects the different approach to feeding in the areas rearing dairy replacements and the areas where cattle are fattened.

Grazing

Only 11 out of 168 farmers reported supplementary concentrate feeding. Grazing was classed as "good" on 60 farms, as "moderate" on 72 farms, and as "poor" on 31 farms (no report from 5). For the first time, all five areas recorded fewer farms with "good" grazing than with "moderate". Since the same farms were being considered for all age groups, the gradual deterioration in grazing can only mean that the older animals were deliberately given the poorer grazing.

Outwintering

About a third of the farmers left their young cattle out of doors for all or part of the winter. If outwintering implies leaving the animals out all the year round, 40 farmers or 20 per cent of the total were prepared to let their animals face the long, cold, and damp winters of the Region out of doors.

Housing and Hygiene

A visual assessment was made of structure, lighting and ventilation of houses for calves (up to 6 months) and young stock (6–24 months), and of the condition of feeding pails (where used), troughs, bedding,

and water supply. On 74 per cent of the farms, calf houses were considered satisfactory, the proportion rising to 80 per cent for young cattle. Twelve farms had dirty pails, 14 dirty troughs, 62 dirty bedding, and 13 fouled water out of about 200 on which reports were made.

Condition of Animals

Weights or measures being impracticable, condition was assessed visually and was merely a personal opinion. No attempt was made to distinguish between degrees of good rearing. Any animals of good commercial standard or better were classed as "good", those falling short of this standard as "moderate", and the badly reared animals as "poor" or "very poor".

Table 3
Condition of Calves and Young Stock
(totals for all areas)

	Good		Moderate		Poor		Very Poor		Total
	No.	%	No.	%	No.	%	No.	%	
Up to 6 months	1,354	76·2	352	19·8	61	3·4	10	0·6	1,777
6–12 months	867	66·1	327	24·9	101	7·7	17	1·3	1,312
12–24 months	1,739	65·5	646	24·3	234	8·8	37	1·4	2,656
All ages	3,960	68·9	1,325	23·1	396	6·9	64	1·1	5,745

Taking the animals of all age groups up to two years, in all areas, 69 per cent were classed as "good", 23 per cent as "moderate", 7 per cent as "poor", and 1 per cent as "very poor". The two Northern rearing areas had no animals classed as "very poor" and the Yorkshire Dales area had only 2 per cent classed as "poor".

When the animals were divided into age groups it was at once apparent that condition deteriorated with age. Thus, only 4 per cent of the calves were classed as "poor" or "very poor"; in the 6–12 months group the proportion in these two categories had risen to 9 per cent, and above 12 months the proportion rose to 10·2 per cent. At the same time, the proportion of "good" animals fell by 10 per cent and the "moderates" rose by 5 per cent.

The distribution of the 8 per cent of "poor" or "very poor" animals was fairly wide; 40 per cent of the farms had one or more animals so classified. Almost 90 per cent of the farms, carrying 93 per cent of the animals, had all or some animals classed as "good"; only 11 per cent

had no animals classed better than "moderate" and they carried only 7 per cent of the animals. There was clearly some correlation between housing, hygiene, and condition. For example, of the 53 farms whose calf houses were considered unsatisfactory, 41 had some animals classed as "poor" or "very poor". Dirty pails were reported on 12 farms and 10 of these farms had cattle in the lowest categories.

It is always possible for the odd animal to do badly in the best of herds and, in the final assessment of reasons why calves had to be classed as "poor" or "very poor", those farms with only one such animal were omitted. This left 58 farms, or 28 per cent of the total, which had two or more animals classed as "poor" or "very poor", the total number of such animals being 436. Three main reasons and combinations of them were given for poor condition. Poor housing alone affected only 5 per cent of the 58 farms and 2 per cent of the animals, but in combination with shortage of food and disease it affected 55 per cent of the farms and 61 per cent of the animals. Disease alone accounted for only 1 per cent of the "poor" animals spread over 5 per cent of the 58 farms. The most potent factor, alone or in combination with the other factors, was inadequate feeding. No less than 40 farms—69 per cent of those with "poor" animals and 20 per cent of the total number of farms surveyed —had two or more animals suffering from poor nutrition. The number of animals so affected was 354—82 per cent of all the poor animals and 6 per cent of all the animals (5,745) of which a record of condition was made.

Although the number of obviously undernourished animals was only 6 per cent of the total, the fact that 20 per cent of the farms visited carried cattle suffering in this way suggests that there is ample room for improvement in the management of young cattle.

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